CLAIMS

We claim:

1.   A method of determining the profile of an integrated circuit structure, comprising:

obtaining a measured metrology signal;

obtaining a first simulated metrology signal, the first simulated metrology signal having an associated profile model of the structure, wherein the associated profile model is defined by a set of profile parameters; and

when the measured metrology signal and the first simulated metrology signal match within a first termination criterion,

a)   selecting at least one profile parameter from the set of profile parameters of the profile model associated with the first simulated metrology signal;

b)   determining a value for the selected profile parameter;

c)   obtaining a second simulated metrology signal having an associated profile model of the structure defined by a set of profile parameters with at least one profile parameter equal or close to the determined value for the selected profile parameter; and

d)   when the measured metrology signal and the second simulated metrology signal match within a second termination criterion, determining values for one or more remaining profile parameters from the set of profile parameters of the profile model associated with the second simulated metrology signal.

2.   The method of Claim 1 further comprising:

generating a library of simulated metrology signals and associated profile models, the library generated with all profile parameters floating over ranges of values, wherein the first simulated metrology signal is obtained from the library.

3.   The method of Claim 2 further comprising:

when the measured metrology signal and the first simulated metrology signal do not match within the first termination criterion, obtaining another simulated metrology signal from the library.

4.   The method of Claim 2 wherein the second simulated metrology signal is obtained from the library, and wherein when the measured metrology signal and the second simulated metrology signal do not match within the second termination criterion, obtaining from the library another simulated metrology signal having at least one profile parameter equal or close to the determined value for the selected profile parameter.

5.   The method of Claim 4 wherein the second metrology signal has one or more remaining profile parameters equal or close to one or more remaining profile parameters of the first simulated metrology signal.

6.   The method of Claim 4 further comprising:

generating a subset of the library having a subset of the simulated metrology signals and associated profile models,

wherein the set of profile parameters of the profile models in the subset of the library have at least one profile parameter equal or close to the determined value for the selected profile parameter, and

wherein the second simulated metrology signal and/or the another simulated metrology signal are obtained from the subset of the library.

7.   The method of Claim 4 wherein when the measured metrology signal and the second or another simulated metrology signal match within the second termination criterion, the values for the one or more remaining profile parameters are determined from the set of profile parameters that define the profile model corresponding to the second or another simulated metrology signal.

8.   The method of Claim 2 wherein obtaining the second simulated metrology signal comprises:

generating the second simulated metrology signal using a set of profile parameters having at least one profile parameter equal or close to the determined value for the selected profile parameter; and

when the measured metrology signal and the second simulated metrology signal do not match within the second termination criterion, generating another simulated metrology signal using a set of profile parameters having at least one profile parameter equal or close to the determined value for the selected profile parameter.

9.   The method of Claim 8 further comprising:

determining one or more remaining profile parameters for the second or another simulated metrology signal using optimization techniques, global optimization techniques, or a combination of global and local optimization techniques.

10.   The method of Claim 9 wherein when the measured metrology signal and the second or another simulated metrology signal match within the second termination criterion, the values for the one or more remaining profile parameters are determined from the set of profile parameters that define the profile model corresponding to the second or another simulated metrology signal.

11.   The method of Claim 1 wherein obtaining the first simulated metrology signal comprises:

generating the first simulated metrology signal using a set of profile parameters; and

when the measured metrology signal and the first simulated metrology signal do not match within the first termination criterion, generating another simulated metrology signal using a set of profile parameters having at least one profile parameter different than the profile parameters of the first simulated metrology signal.

12.   The method of Claim 11 further comprising:

determining the set of profile parameters for the another simulated metrology signal using optimization techniques, global optimization techniques, or a combination of global and local optimization techniques.

13.   The method of Claim 11 wherein obtaining the second simulated metrology signal comprises:

generating the second simulated metrology signal using a set of profile parameters having at least one profile parameter equal or close to the determined value for the selected profile parameter; and

when the measured metrology signal and the second simulated metrology signal do not match within the second termination criterion, generating another simulated metrology signal using a set of profile parameters having at least one profile parameter equal or close to the determined value for the selected profile parameter.

14.   The method of Claim 13 further comprising:

determining one or more remaining profile parameters for the second or another simulated metrology signal using optimization techniques, global optimization techniques, or a combination of global and local optimization techniques.

15.   The method of Claim 11 wherein the second simulated metrology signal is obtained from a library of simulated metrology signals and associated profile models, and wherein when the measured metrology signal and the second simulated metrology signal do not match within the second termination criterion, obtaining from the library another simulated metrology signal having at least one profile parameter equal or close to the determined value for the selected profile parameter.

16.   The method of Claim 15 wherein the second metrology signal has one or more remaining profile parameters equal or close to one or more remaining profile parameters of the first simulated metrology signal.

17.   The method of Claim 15 further comprising:

generating a subset of the library having a subset of the simulated metrology signals and associated profile models,

wherein the set of profile parameters of the profile models in the subset of the library have at least one profile parameter equal or close to the determined value for the selected profile parameter, and

wherein the second simulated metrology signal and/or the another simulated metrology signal are obtained from the subset of the library.

18.   The method of Claim 1 wherein selecting at least one profile parameter comprises:

determining one or more criteria for selecting the at least one profile parameter; and

selecting one or more profile parameters from the set of profile parameters that meet the one or more criteria.

19.   The method of Claim 18 wherein the one or more criteria, includes an amount of correlation to another profile parameter.

20.   The method of Claim 1 wherein determining the value for the selected profile parameter comprises:

obtaining values from empirical, historical, theoretical, and/or simulated data of the selected profile parameter.

21.   The method of Claim 1 wherein determining the value for the selected profile parameter comprises:

measuring the selected profile parameter with a metrology device.

22. The method of Claim 21 wherein the metrology device is at least one of a reflectometer, an ellipsometer, a scatterometer, a critical dimension scanning electron microscope, an atomic force microscope, or a cross-section scanning electron microscope.

23. The method of Claim 21 wherein the measurement of the selected profile parameter is performed for more than one site and values determined from the measurements are weighted using statistical techniques.

24. The method of Claim 21 wherein the selected profile parameter is film thickness of an underlying film or a width of the structure.

25. The method of Claim 1 wherein the second simulated metrology signal is obtained using at least one of a weighted average optimizer, a sensitivity analyzer, a cluster vector estimator, a dynamic cluster adjuster, a regression-based optimizer, a localized fine-resolution library procedure, and an iterative library refinement procedure.

26. A method of determining the profile of an integrated circuit structure from a measured metrology signal, the method comprising:

developing an optical metrology model for a structure, the metrology model including a profile model of the structure, the profile model comprising profile parameters;

a) selecting a first profile parameter for determination of value;

b) determining the value of the selected first profile parameter;

c) determining values of remaining profile parameters using the determined value of the selected first profile parameter and using one or more measured metrology signals off the structure;

d) setting one or more subsequent termination criteria for terminating parameter predetermination;

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e) selecting a subsequent profile parameter for determination of value;

f) determining the value of the selected subsequent profile parameter; and

g) determining values of remaining profile parameters using the determined values of the selected first and selected subsequent profile parameters and using one or more measured metrology signals off the structure;

h) iterating steps e) to g) until the one or more subsequent termination criteria for parameter predetermination are met.

27. The method of Claim 26 wherein determining the value of the first selected profile parameter comprises:

creating a library of simulated metrology signals and associated profile parameters, the library created with all the profile parameters floating over corresponding ranges of values;

determining a best match simulated metrology signal from the library corresponding to a measured metrology signal; and

accessing a value of the first profile parameter from profile parameter values associated with the best match simulated metrology signal from the library.

28. The method of Claim 27 wherein determining the best match simulated metrology signal from the library comprises:

determining the best match simulated metrology signal from the library utilizing a profile refinement procedure.

29. The method of Claim 27 wherein determining the best match simulated metrology signal from the library comprises:

comparing the measured metrology signal to a subset of library instances, the subset of the library instances corresponding to library instances wherein value of the selected first profile parameter of the library instance is equal or close to the determined value of the selected first profile parameter.

30. The method of Claim 26 wherein determining values of the remaining profile parameters using the determined values of the selected first and selected subsequent profile parameters comprises:

m) setting one or more subsequent termination criteria for regression;

n) determining a set of values for the remaining profile parameters;

o) calculating a simulated metrology signal corresponding to the selected set of values for the remaining profile parameters and the determined value of the first and all subsequent selected profile parameters; and

p) iterating steps n) and o) until the one or more subsequent termination criteria for regression are met.

31. A method of determining the profile of an integrated circuit structure from a measured metrology signal, the method comprising:

developing an optical metrology model for a structure, the metrology model including a profile model of the structure, the profile model comprising profile parameters;

selecting a plurality of profile parameters for determination of value;

determining values of the selected plurality of profile parameters; and

determining values of remaining profile parameters using the determined values of the selected plurality of profile parameters and using one or more measured metrology signals off the structure.

32. The method of Claim 31 wherein determining the values of the selected plurality of profile parameters comprises:

for each selected profile parameter of the plurality of profile parameters:

a) setting one or more termination criteria for regression;

b) selecting a set of values for the profile parameters;

c) calculating a simulated metrology signal corresponding to the selected set of values of the profile parameters;

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d) iterating steps b) and c) until the one or more termination criteria for regression are met; and

e) designating the value of the of the selected profile parameter of the plurality of profile parameters when the one or more termination criteria for regression are met as the determined value of the selected profile parameter of the plurality of profile parameters.

33. The method of Claim 31 wherein determining the values of remaining profile parameters comprises:

creating a library of simulated metrology signals and associated profile parameters, the library created with all the profile parameters floating over corresponding ranges of values;

determining a best match simulated metrology signal from the library corresponding to the one or more measured metrology signals; and

accessing profile parameter values associated with the corresponding best match simulated metrology signal from the library.

34. The method of Claim 33 wherein determining the best match simulated metrology signal from the library corresponding to the measured metrology signal comprises:

comparing the measured metrology signal to a subset of library instances, the subset of the library instances corresponding to library instances wherein values of the selected plurality of profile parameters of the library instance are equal or close to the corresponding determined values of the selected plurality of profile parameters.

35. The method of Claim 31 wherein determining the values of remaining profile parameters comprises:

performing regression utilizing the determined values of the selected plurality of profile parameters with the remaining profile parameters floating over corresponding ranges of values.

36. A method of determining the profile of an integrated circuit structure from a measured metrology signal, the method comprising:

a) setting one or more termination criteria for parametric optimization;

b) developing an optical metrology model for a structure, the metrology model including a profile model of the structure, the profile model comprising profile parameters;

c) selecting a plurality of profile parameters for determination of value;

d) determining values of the selected plurality of profile parameters;

e) ranking the plurality of profile parameters using the one or more termination criteria for parametric optimization;

f) determining values of remaining profile parameters using the determined values of one or more profile parameters of the selected plurality of profile parameters and using at least one measured metrology signal off the structure; and

g) iterating steps c), d), e), and f) until the one or more termination criteria for parametric optimization are met.

37. A system for determining the profile of an integrated circuit structure, comprising:

a parametric processor configured to obtain a measured metrology signal and a first simulated metrology signal, the first simulated metrology signal having an associated profile model of the structure, wherein the associated profile model is defined by a set of profile parameters; and

a profile evaluator coupled to the parametric processor, wherein when the measured metrology signal and the first simulated metrology signal match within a first termination criterion, the profile evaluator is configured to:

a) select at least one profile parameter from the set of profile parameters of the profile model associated with the first simulated metrology signal;

b) determine a value for the selected profile parameter;

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c)   obtain a second simulated metrology signal having an associated profile model of the structure defined by a set of profile parameters with at least one profile parameter equal or close to the determined value for the selected profile parameter; and

d)   when the measured metrology signal and the second simulated metrology signal match within a second termination criterion, determine values for one or more remaining profile parameters from the set of profile parameters of the profile model associated with the second simulated metrology signal.

38.   The system of Claim 37 further comprising:

a library of simulated metrology signals and associated profile models, the library generated with all profile parameters floating over ranges of values, wherein the first simulated metrology signal is obtained from the library.

39.   The system of Claim 38 wherein when the measured metrology signal and the first simulated metrology signal do not match within the first termination criterion, the parametric processor obtains another simulated metrology signal from the library.

40.   The system of Claim 38 wherein the second simulated metrology signal is obtained from the library, and wherein when the measured metrology signal and the second simulated metrology signal do not match within the second termination criterion, the profile evaluator obtains from the library another simulated metrology signal having at least one profile parameter equal or close to the determined value for the selected profile parameter.

41.   The system of Claim 40 wherein the second metrology signal has one or more remaining profile parameters equal or close to one or more remaining profile parameters of the first simulated metrology signal.

42.   The system of Claim 40 further comprising:

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a subset of the library having a subset of the simulated metrology signals and associated profile models,

wherein the set of profile parameters of the profile models in the subset of the library have at least one profile parameter equal or close to the determined value for the selected profile parameter, and

wherein the profile evaluator obtains the second simulated metrology signal and/or the another simulated metrology signal from the subset of the library.

43.   The system of Claim 40 wherein when the measured metrology signal and the second or another simulated metrology signal match within the second termination criterion, the profile evaluator determines the values for the one or more remaining profile parameters from the set of profile parameters that define the profile model corresponding to the second or another simulated metrology signal.

44.   The system of Claim 38 wherein the profile evaluator obtain the second simulated metrology signal by:

generating the second simulated metrology signal using a set of profile parameters having at least one profile parameter equal or close to the determined value for the selected profile parameter; and

when the measured metrology signal and the second simulated metrology signal do not match within the second termination criterion, generating another simulated metrology signal using a set of profile parameters having at least one profile parameter equal or close to the determined value for the selected profile parameter.

45.   The system of Claim 37 wherein the parametric processor obtains the first simulated metrology signal by:

generating the first simulated metrology signal using a set of profile parameters; and

when the measured metrology signal and the first simulated metrology signal do not match within the first termination criterion, generating another simulated metrology

signal using a set of profile parameters having at least one profile parameter different than the profile parameters of the first simulated metrology signal.

46. The system of Claim 45 wherein the profile evaluator obtains the second simulated metrology signal by:

generating the second simulated metrology signal using a set of profile parameters having at least one profile parameter equal or close to the determined value for the selected profile parameter; and

when the measured metrology signal and the second simulated metrology signal do not match within the second termination criterion, generating another simulated metrology signal using a set of profile parameters having at least one profile parameter equal or close to the determined value for the selected profile parameter.

47. The system of Claim 45 further comprising:

a library of simulated metrology signals and associated profile models, wherein the profile evaluator obtains the second simulated metrology signal from the library, and wherein when the measured metrology signal and the second simulated metrology signal do not match within the second termination criterion, the profile evaluator obtains from the library another simulated metrology signal having at least one profile parameter equal or close to the determined value for the selected profile parameter.

48. The system of Claim 47 further comprising:

a subset of the library having a subset of the simulated metrology signals and associated profile models,

wherein the set of profile parameters of the profile models in the subset of the library have at least one profile parameter equal or close to the determined value for the selected profile parameter, and

wherein the profile evaluator obtains the second simulated metrology signal and/or the another simulated metrology signal from the subset of the library.

49. The system of Claim 37 further comprising:

a metrology device configured to measure metrology signals off the wafer structure and transmit the measured metrology signals, the metrology device coupled to the parametric processor and the profile evaluator.

50. The system of Claim 49 wherein the metrology device is a reflectometer or an ellipsometer.

51. The system of Claim 37 wherein the parametric processor selects the one or more profile parameters based on correlation of a selected profile parameter of the one or more profile parameters to another one or more profile parameters.

52. The system of Claim 51 wherein the selected profile parameter is a film thickness or a structure width.

53. The system of Claim 37 wherein the parametric processor is further configured to:

apply mathematical and/or statistical techniques to determine the value of the selected one or more profile parameters from empirical, historical, theoretical, and/or simulation data and/or measurements obtained with metrology devices.

54. A computer-readable storage medium containing computer executable code to determine the profile of a wafer structure from a measured metrology signal by instructing a computer to operate as follows:

developing an optical metrology model for a structure, the metrology model including a profile model of the structure, the profile model comprising profile parameters;

a) selecting a first profile parameter for determination of value;

b) determining the value of the selected first profile parameter;

c) determining values of remaining profile parameters using the determined value of the selected first profile parameter and using one or more measured metrology signals off the structure;

d) setting one or more subsequent termination criteria for terminating parameter predetermination;

e) selecting a subsequent profile parameter for determination of value;

f) determining the value of the selected subsequent profile parameter; and

g) determining values of remaining profile parameters using the determined values of the selected first and selected subsequent profile parameters and using one or more measured metrology signals off the structure;

h) iterating steps e) to g) until the one or more subsequent termination criteria for parameter predetermination are met.

55. A computer-readable storage medium of Claim 54 containing computer executable code further instructing a computer to operate as follows:

m) setting one or more subsequent termination criteria for regression;

n) determining a set of values for the remaining profile parameters;

o) calculating a simulated metrology signal corresponding to the selected set of values for the remaining profile parameters and the determined value of the first and all subsequent selected profile parameters; and

p) iterating steps n) and o) until the one or more subsequent termination criteria for regression are met.

56. A computer-readable storage medium containing computer executable code to determine the profile of a wafer structure from a measured metrology signal by instructing a computer to operate as follows:

a) setting one or more termination criteria for parametric optimization;

b) developing an optical metrology model for a structure, the metrology model including a profile model of the structure, the profile model comprising profile parameters;

c) selecting a plurality of profile parameters for determination of value;

d) determining values of the selected plurality of profile parameters;

e) ranking the plurality of profile parameters using the one or more termination criteria for parametric optimization;

f) determining values of remaining profile parameters using the determined values of one or more profile parameters of the selected plurality of profile parameters and using at least one measured metrology signal off the structure; and

g) iterating steps c), d), e), and f) until the one or more termination criteria for parametric optimization are met.